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THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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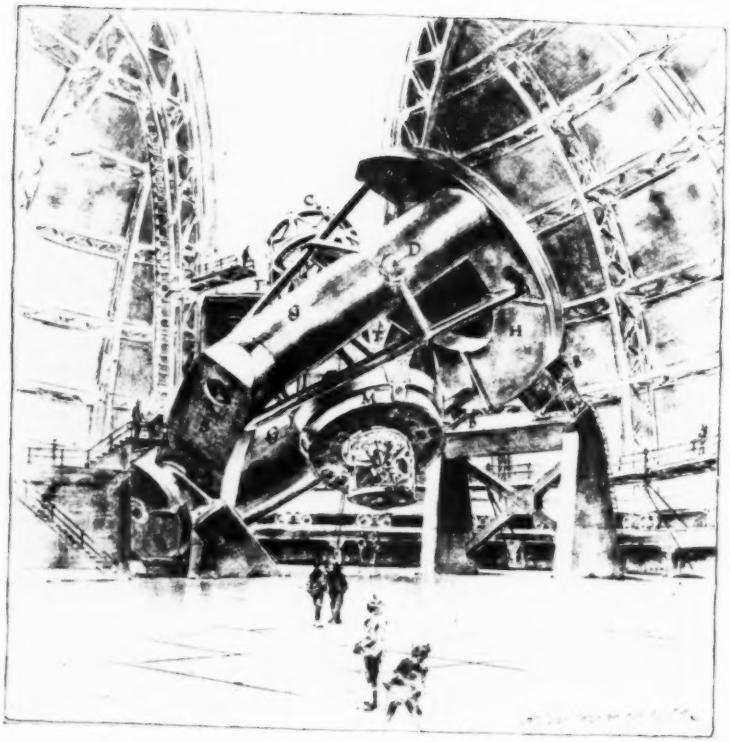
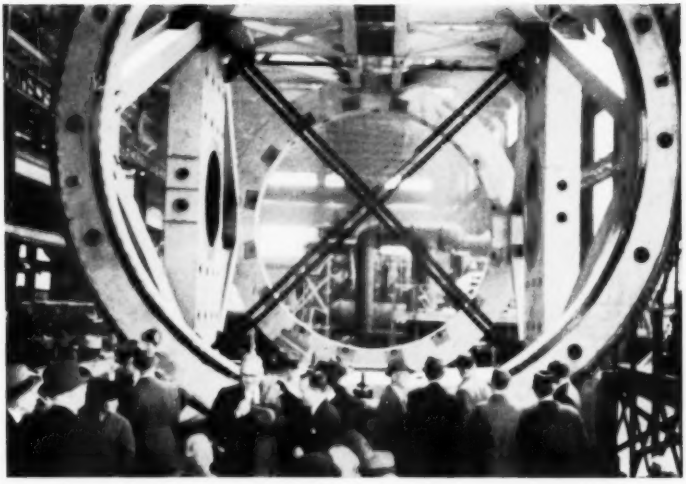


THE 200-INCH TELESCOPE
From a sketch by R. W. Porter.

PLATE VII



THE TUBE OF THE 200-INCH TELESCOPE.

Above.—Fitting the last bolt in the tube, April 30, 1937.

Below.—A view of the tube at the time of the ceremony (the cross braces are temporary).

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COMPLETION OF THE TUBE OF THE 200-INCH TELESCOPE

By C. A. CHANT

(With Plates VI, VII)

AFTER years of doubt as to the suitability of the great disc of glass which had been received from France, the 100-inch telescope of the Mount Wilson Observatory was completed in 1918; and it was not long after this that Dr. George E. Hale, the director of the observatory, began to advocate a still larger and better instrument. This time he proposed one with an aperture twice as large. He pondered and discussed his proposal until in 1928 the Rockefeller Foundation provided $6,000,000 for him to realize his dream, i.e., to build and house a telescope 200 inches in diameter.

At first it was thought that the only suitable material for the mirror was fused quartz, which has an extremely small coefficient of expansion by heat, but after several years' experimenting in the production of large discs of quartz this proposal was abandoned. The Corning Glass Works then undertook the development of a type of "Pyrex" glass with a specially low coefficient of expansion for the mirror. It was also decided to make the disc honeycombed at the back, thus reducing the weight and allowing it to change in temperature more rapidly. After much study and preliminary experimental research the disc for the mirror was poured on December 2, 1934. An unprecedented flood in the following summer aroused grave fears as to the safety of the disc, but it was removed from the annealing oven on December 8, 1935, apparently in excellent condition. It was shipped on March 26, 1936, and on April 10 it arrived at Pasadena where it is being ground to shape. The hope is expressed that it may be finished in 1940.

Meantime the mounting for the telescope had received much attention. Several designs were considered. One of the fork type seemed to be favoured in 1931, but it was finally discarded for a form of yoke of a somewhat novel pattern, in which the upper bearing is modified to permit observation of the stars near the pole.*

A view of the adopted mounting from a sketch by R. W. Porter, who for some years has been employed on the design of the telescope, is shown in Plate VI. The material used throughout is ordinary hot-rolled low-carbon steel. The tube *T* is 22 feet in diameter, 57 feet long and weighs 88 tons. This includes the cage *C* at the top but not the mirror cell *M* at the bottom. The general type of construction is the hollow steel box structure, which makes it very stiff and yet not massive. To give further rigidity to the tube, the focal length chosen for the mirror was 3 1/3 times the aperture, or 666 inches. In the 100-inch the focal length is 500 inches, or the ratio is 5 to 1. In this way the new mounting is more "bunty" in appearance than in other large telescopes.†

In the chosen mounting the upper bearing of the polar axis is a mighty horseshoe *H*, which has outer diameter 46 feet, inner diameter 24 feet, thickness 4 feet and which weighs 175 tons. It is made from one-inch plate welded on four-inch curved plate, and to prevent distortion each section is afterwards annealed at 1150°F. The two side girders *G, G* are 50 feet long, 10 feet 6 inches outer diameter and made from one-inch metal. The south end beam *S* is 46 feet long, 10 feet 6 inches wide and 5 feet thick. The yoke is strengthened by various braces seen in the picture and its weight is 185 tons. One end of the declination axis is at *D*. The horseshoe is supported on two oil "pads" *B, B*, the oil being pumped into these bearings under considerable pressure. This is a new idea in telescope mountings but the Westinghouse firm state that they have used it on large balancing machines for many years.

The contract for the construction of the mounting was awarded to the Westinghouse Electric and Manufacturing Company on January 25, 1936. This firm has the necessary equipment and facilities for a project of such magnitude in their turbine plant in South Philadelphia.

*A photograph of a telescope mounted in this way, made by Dr. H. Paige Bailey, was reproduced in this JOURNAL (December 1936) in one of Mr. H. Boyd Brydon's articles on telescope mountings.

†In the 74-inch telescope of the David Dunlap Observatory the ratio is 4.8 to 1.

The tube and the mounting are constructed in welded sections as large as can be handled, and these sections are machined and bolted together to form a larger unit. The largest single section is the cage on the top of the tube, which is 22 feet in diameter and 12 feet high and weighs 13 tons. A special annealing oven had to be built to accommodate it. The heaviest single piece is the central part of the horseshoe. Its dimensions are 45 feet by 15 feet by 4 feet and it weighs 60 tons. All the other single sections can be handled at the South Philadelphia shop, but for the final machining of the outer surface of this section it must be taken to the Westinghouse works at East Pittsburgh. The weight of the entire mounting is 450 tons.

The work in the shop was started June 15, 1936, and the entire job is expected to be completed by July 1, 1937.

The tube was finished first and a number of guests were invited to witness the ceremony of placing the last bolt on April 30. On that date about seventy-five astronomers, engineers and others assembled at the city office of the company and were conveyed by buses to the shops. At 11.30 Mr. G. H. Froebel, Chairman of the Reception Committee, opened the proceedings and Mr. A. W. Robertson, Chairman of the Board of the Westinghouse firm gave an address of welcome. Then Mr. Jesse Ormondroyd, who was one of the engineers on the design of the mounting, gave an address on "Engineering Aspects of Telescopic Construction". Mr. Ormondroyd is now on the staff of the University of Michigan. Then the final bolt in the telescope tube was put in place by Mr. William Ladley, veteran employee with 48 years of service with the firm. (Plate VII). After the ceremony the guests made a tour of the manufacturing plant. Members of the reception committee conducted small groups of the visitors and explained the different parts of the mounting of the telescope and also the numerous steam turbines, many of large size, in course of construction. The manner in which the extreme demands for precision in the most difficult sort of complex machinery are attained was admired by all. Then a very pleasant lunch was served in the works at 2.00 p.m. and at 3.00 the guests were conveyed back to Philadelphia.

Dr. R. K. Young and the writer had the privilege of being present at the ceremony and to the Company and especially to Mr. G. H. Newton, who conducted us through the Works, our sincere thanks are due.

TWO UNUSUAL AURORAL DISPLAYS OBSERVED FROM THE DUNLAP OBSERVATORY

By PETER M. MILLMAN

WITH the approach of sunspot maximum we may expect to see a greater number of auroral displays and during the spring of 1937 the writer was fortunate enough to see two which were somewhat out of the ordinary. The point of observation was, in both cases, the Dunlap Observatory, lat. 43° 52′ N., long. 79° 25′ W.

The first display appeared on the night of Feb. 2-3, 1937. Earlier in the evening auroral zones were seen in the north but at 10.55 p.m. E.S.T. these gave way to a display of rays (types IIA and IID) which covered most of the northern sky. These were all of the normal greenish-white colour except for two or three large rays about 10° north of the east point and extending from the horizon to altitudes of 10° to 20°. These latter were of a uniform orange red colour similar to the shade seen over a burning building on a hazy night. The red rays faded at 11.10 p.m. E.S.T. and did not appear again though the general auroral display increased in brightness and extent and by midnight covered the whole northern half of the sky and extended well south of the zenith. Most of the aurora had disappeared by 3.30 a.m.

A communication from Prof. C. Störmer informs me that the same red rays were observed by an officer on the steamship *Winnipeg* in the North Atlantic. Prof. Störmer calculates that these rays extended up to a height of 500 km. over a point a little east of Cape Race.

The second unusual display was seen on the night of Apr. 30. It was first noted at 9.03 p.m. E.S.T. as an isolated luminous band about 20° long and 5° wide just to the south of Corona. This rapidly lengthened in an east-west direction till by 9.30 p.m. it extended in a bright band not quite 3° wide and over 140° long from δ Ophiuchi to ε Geminorum. From 9.05 to 9.40 this display moved south in a direction perpendicular to its length at a speed of very nearly one degree per minute. The only other indication of auroral activity at the time was a few faint but sharp rays near the north horizon. At 9.40 p.m. a series of small dark striations appeared across the eastern half of the bright band and these kept

moving rapidly along it to the west. Shortly after this the band began to lose its definite form, became fainter, and faded from the eastern end, being last seen as a faint oval patch of luminescence in Cancer at 9.55 p.m. The band, throughout its development, seemed to be of a pure white colour.

This same display was observed by Mr. Bert Topham in West Toronto and by Miss R. J. Northcott in North Toronto at a point 8.8 miles south of the Observatory. Miss Northcott made three plots of the band at intervals of 5 to 10 minutes and these placed it consistently 4° north of the plots made at the same times at the Dunlap Observatory. The above parallax gives the height of the band on the meridian as 100 miles above the earth over a point about 40 miles south of Toronto. Of course this height is extremely uncertain owing to the short base-line but at least it indicates that the band was probably somewhat higher than the zone of maximum auroral frequency at an altitude near 60 miles.

It is interesting to note that Prof. Bobrovnikoff in *Popular Astronomy* for June-July, 1937, describes a very similar display seen three nights earlier. What Bobrovnikoff describes as globes of light travelling along the band to the west is probably the same effect I have mentioned above. To me, however, they had more the appearance of dark markings impressed on a bright band which could, when looked at in another way, be considered as dividing the band up into a series of bright segments or globes.

David Dunlap Observatory,
Richmond Hill, Ontario.

RADIO TALKS OVER CFCT, VICTORIA, B.C.

By W. E. Harper

No. 88.—WHAT ASTRONOMERS READ

In any calling or profession it is important to keep in touch with the findings of other workers in the same field and to learn of all the latest developments. This is particularly urgent in our own branch of science for the discoveries that are taking place in astronomy and allied sciences to-day are so numerous and far-reaching that one simply has to be familiar with them to do the most effective work. Indeed a person's whole time might be taken up in reading about what other workers are doing and the results they are achieving if one did not exercise judgment and discrimination in one's mental diet.

The reading matter that comes to our library shelves is of three kinds. There are books by outstanding writers on astronomy or allied sciences that we feel advisable to have and which are accordingly secured. Then there are periodicals, magazines and journals which are issued weekly, monthly, quarterly or occasionally yearly, which give a general discussion of problems and in some cases a summary of the author's results. The third type of literature received comes directly from the individual observatories scattered over the world and deals with their individual observations and results in more or less detail. These latter are very varied as to size and composition, sometimes being a simple leaflet and in other cases a ponderous volume. They go by various designations as annals, bulletins, circulars, communications, observations, news letters and what not.

Most of these publications just mentioned as coming to us from other observatories are received in exchange for our publications, although I'm afraid we do not always comply with every request made upon us. Every observatory or university laboratory doing effective work in astronomy or related sciences is, however, upon request, put upon our mailing list, which now numbers approximately 400.

In the earlier days records were kept of all publications received;

now a limited list only is entered for record. The reason was simply that with a mass of material coming in, a great deal of it was never perused and automatically it went to the library annex. There might be much wheat in it but to find it among the chaff would consume more time than the astronomer felt was fitting and he stuck to the recognized standard publications. This undigested material has recently been thoroughly gone over, a few worthy periodicals and publications salvaged and the rest, which deals with matters not in our own immediate line, such as geography, geophysics, magnetism, meteorology and oceanography, has been discarded. It is not that such material is valueless, but to ourselves it is practically so, to say nothing of the space it occupies being required for other things. These fifty-odd periodicals will not be listed on our receiving records in future.

Even with this weeding out process performed you will agree with me that we are in no danger of starving for astronomical literature since the different periodicals and publications still being listed number 392. There are approximately 50 of what may be called the principal periodicals, mostly monthly, while the remainder are observatory publications, in some cases several slightly different publications coming from the one and the same observatory. The total observatory publications for the leading countries are as follows:

United States	75	Russia	26
Germany	43	Canada	17
England	32	Japan	14
Italy	30	Poland	12
France	29	Sweden	10

Thirty other countries contribute from one to seven each. It is only natural that the United States with its numerous observatories should head the list. Ten years ago Russia would not have appeared so high up on the list but she is making great strides to catch up in astronomical science. While she has as yet no telescope over 40 inches in aperture, nevertheless some good work is being done on variable stars at several observatories and the journals containing such investigations are now in demand.

As for the periodicals that come to us at regular intervals, weekly, monthly or quarterly, the United States again leads with England a close second. The numbers are, United States 14, England 11, Germany 7, Canada and Japan 4 each. Other countries have one or two each. The *Astrophysical Journal* issued from the Yerkes Observatory, University of Chicago, is one of the most outstanding monthlies for it numbers among its contributors prominent men of all countries. More popular treatises are given in the *Popular Astronomy* and the *Publications of the Astronomical Society of the Pacific*. From England comes *Monthly Notices*, a magazine of very high excellence, packed with the very latest theories concerning the universe that a brilliant school of English mathematicians and physicists such as Eddington, Jeans, Milne and others, produce. Foreign contributors of course are welcomed, in this publication as well as in the American journals.

It is impossible for one having a heavy program of observation with the telescope to digest all that is written. What he can do is to select from the titles those articles he deems most helpful in his own immediate problem. In this he is aided still further by a little publication entitled "Science Abstracts" which aims to summarize in a paragraph the leading thought of every article in every such magazine throughout the world. The "Readers Digest" would be a somewhat analogous publication in the literary realm. The *Astronomischer Jahresbericht*, a yearly German publication, is also invaluable since it summarizes and classifies every published article on astronomy.

Through co-operation more ground is covered. From time to time for upwards of an hour the members of the staff come together, when one member gives a digest of some leading article or series of articles related to his own work and such summaries and resulting discussion are helpful to all. During the past ten years 380 of such meetings have been held.

It might be stated in closing that the majority of the leading journals are bound in permanent form and catalogued at the end of the year. Upwards of 2,000 bound volumes dealing with astronomy and related sciences are now upon our library shelves.

No. 89.—AMATEUR ASTRONOMY IN CANADA

In a former radio talk I dealt with the work of amateur astronomers the world over, citing many cases of valuable contributions from workers in different countries of the world. I did not, as it happened, say anything about amateurs in Canada; for which omission I was taken to task by one who felt I had failed to recognize that we have a body of amateur astronomers in Canada doing good work. No intentional slight was implied by this omission; it was simply a case of the lack of time coupled with ordinary courtesy of recognizing workers elsewhere instead of dwelling upon our own.

However, such criticism furnishes me with a topic for this evening's short chat with you and I purpose mentioning a few things accomplished by Canadian amateur astronomers. At the very outset I pay tribute to the work of this group by stating that had it not been for their encouragement of the study of the science and their influence in urging that better facilities for its study be provided we might not yet have a national observatory and consequently no such research institution as the local Astrophysical Observatory.

While the present organization—the Royal Astronomical Society of Canada—includes professionals, it is almost entirely a group of amateur astronomers. There are Centres at Toronto—its birthplace and present headquarters—at London, Hamilton, Ottawa, Montreal, Winnipeg, Calgary, Edmonton, Vancouver and our own city, so that the thousand odd members composing it are not confined to any one locality but are scattered from coast to coast.

While the official publications of this Society date back only to 1889 I wish to mention one great achievement of a small group of Canadian scientists, astronomers really, prior to that time. It was through the persevering work of a small committee of amateurs headed by Sandford Fleming that standard time was introduced to the world in 1883. Possibly it was by reason of our country's vast extent from the Atlantic to the Pacific that made the problem so particularly pressing for us when the East was being connected with the West by means of a transcontinental railway. Hitherto each city or hamlet used its own local sun time but the standardization of railway time tables necessitated the adoption of zones in

which uniform time was used. Thus five great zones, each one hour wide, were adopted for Canada with corresponding ones for the United States. Thus we have Atlantic, Eastern, Central, Mountain and Pacific standard times for our country, with corresponding ones for European and Oriental countries. This great boon to time-reckoning the world over came about through the persistent agitation and education furnished by the predecessors of our present body of Canadian amateur astronomers.

The second great change in which our Canadian amateur astronomers play no small part was the unification of the civil and astronomical day. The civil day began at midnight, the nautical day twelve hours earlier, the astronomical twelve hours later. At the Washington Conference of astronomers in 1884 it was recommended, possibly without proper appreciation of the difficulties that would ensue, that the astronomical day begin at midnight like the civil day. Curiously enough, it was a Canadian-born astronomer, Newcomb, then head of the Nautical Almanac office at Washington, whose stout opposition to the proposal delayed it for four decades. The Canadian astronomical society, however, kept alive the agitation and won over many of the leading American astronomers, so that in 1918 they voted three to one for the change. Shortly thereafter, by international agreement, the 1st day of January, 1925, was selected as the date when the change was to be made, and both civil and astronomical time to be reckoned from midnight.

About the year 1908 when a number of orbits of spectroscopic binaries had been determined, it was an amateur member of the Astronomical Society at the Toronto Centre, J. Millar Barr by name, who drew attention to a curious feature of the orbital elements. Several stars with apparently small orbits seemed to have their major axes aligned in the same direction from the earth. The unlikelihood of such a curious arrangement focussed attention on these particular stars, with the result that they were shown to be not true binary systems but merely pulsating stars.

As the star swelled up in size the atmosphere nearest us would show a velocity of approach, whilst when it contracted the atmosphere would be receding and thus the velocities would vary over a small range. It was no small achievement for an amateur to have

the honour of directing the attention of the professional astronomers to evidence which classes these stars as Cepheid variables.

So much for work of several years ago. Present day efforts of our amateur astronomers are directed largely to the making of telescopes with which they may the better study the heavens. Here in Victoria we have a telescope-making section of the Local Centre which meets regularly under one of its own leaders, Mr. W. R. Hobday, and is busily engaged in making reflecting telescopes. About half a dozen were completed last year, some as large as eight inches in diameter, and all are of excellent quality. Those who visited the Hall of Science at the local Exhibition last autumn must have been duly impressed with the high calibre of the work being carried on here in our midst. , Similar enthusiasm for the making of reflecting telescopes is evident right across the Dominion, though possibly it is not quite so pronounced as here, where naturally the big 72-inch telescope gives a certain stimulus to the work.

When telescopes such as these become more numerous we may look for the next step which is their use in observing variable stars and recording their variations in brightness. Such work, which is most efficiently performed in collaboration with professional astronomers, is expected in the near future.

At Toronto and eastern points some valuable work in the observation of meteors is now being carried out under the supervision of Dr. Millman of the David Dunlap Observatory. Such plotting of the paths of the meteors which flash across the sky at certain periods of the year gives us valuable information about the upper atmosphere, as indicated in an earlier talk. Some mention should be made also of the work of Mr. A. F. Miller, long associated with the Toronto Centre. In addition to ordinary visual work at the telescope, he carried out spectroscopic observations. His equipment was purchased some few years ago by our own Mr. H. Boyd Brydon and has been the means of giving valuable instruction to local members.

Altogether the contribution being made by our Canadian amateurs is quite a worthy one and I'm glad it was suggested to me that I should recognize such work in these talks.

No. 90.—THE MAKING OF TELESCOPE MIRRORS

A short time ago I discussed with those who were listening in, the contributions made to the science of Astronomy by our Canadian amateurs. In closing, I dwelt upon the present day interest in the making of mirrors for reflecting telescopes and referred to the fact that several such mirrors had been made last year in Victoria by those enrolled in the telescope-making section of the local Centre of the Royal Astronomical Society of Canada.

Briefly, the process consists of taking a glass disk of the desired diameter, say ten inches, like those from the porthole of a ship, grinding one surface slightly concave and then depositing a coat of silver on that surface to serve as the reflector. If the desired focal length be ten feet, the surface is first ground out so that it would fit snugly over a portion of the surface of a sphere having a radius of twenty feet. If the mirror is left in this shape and silvered it will give respectable images of the heavenly bodies, but they will not be as clear cut and defined as it is possible to obtain. The reason is that the rays of light which fall on the outer portions of the disk are brought to a slightly different focus than those from the central portion. To overcome this defect the surface of the mirror has to be further changed by grinding out a little more of the central region, gradually tapering off to zero at the edge. This makes the surface paraboloidal in form, as technically described, and ensures that all rays of light coming from a distant object are brought to a pin point focus. The amount that has to be ground out of the central portion is of course infinitesimally small and one has to proceed cautiously, testing by optical means to make sure that just the right amount is ground out at each distance from the centre. At the very centre itself for the ten inch mirror under consideration the extra depth would be only 1/4000 inch.

When once the mirror has been ground to the paraboloidal form the coating of silver offers no great difficulty. It is usually deposited chemically and in a former talk I described the procedure followed in handling the big 72-inch mirror which with its cell weighs something over three tons. Two pounds of silver are required for each

silvering, which is done twice yearly, a fresh coat having been given to it last week.

The newest process is depositing a coat of aluminum on top of a coat of chromium, both being carried out in a very high vacuum. Under these conditions a fine reflecting surface is secured, being almost as good as polished silver with the added advantage of being much more permanent. The method is so recent that no lengthy tests are yet available, but it is expected that the coat will stand up for at least five years in comparison with the six-months' life of the silver coating.

When it was found possible to deposit a coat of uniform thickness of this chromium-aluminum type, experiments were shortly afterwards undertaken at the Mount Wilson Observatory to see if they could control the deposit to give varying depths at different parts of the mirror. In ordinary work the aluminum or chromium electrodes are spaced at regular intervals near the surface to be covered and when the electric current is turned on atoms of these substances are set free and deposit on the surface.

Now by making a screen of a certain shape, placing this in front of the mirror and rotating it, we can see that it is possible to control the amount of deposit that reaches any particular part of the disk. In this way it is possible to build up the deposit much thicker at some parts than at others and so change the figure of the mirror undergoing treatment. This is bound to revolutionize the making of mirrors especially in the final stages. It will never do away with the optician, for the rough grinding must be done and the mirror brought to the approximate form desired. It is the final stages though which require so much time, as it is necessary to test optically after each slight amount of mirror has been removed. In a big mirror this means long delays, for even the slightest amount of polishing raises the temperature and it becomes necessary to allow the mirror to stand for about a day before such optical tests are advisable. Moreover, if by any error of judgment one proceeds too far in removing material from the surface it becomes a painful necessity to start over again from the very beginning. Under the new method if one should deposit too much it is a simple matter to dissolve some of it away until the right amount is secured.

The time required for doing this work is in its favour. It is stated by Professor Strong of Mount Wilson, who aluminized both our nineteen inch mirrors, giving them a uniform deposit, that a twelve inch mirror can be made parabolic in half a day, whereas previously weeks, if not months, were required under the former method of grinding and polishing. One can see that the method may lead to the production of cheap, small reflecting telescopes for the use of schools and amateur astronomers.

Another possible application will be in correcting the figure of existing mirrors where they are not accurate. At present it is not possible to deposit a thickness greater than 1/20,000 of an inch without other disturbing factors becoming noticeable, but if the mirror's surface is true to this amount then the hills and hollows can be smoothed out by the new process at the same time as the mirror is being aluminized.

Quite recently too the method of aluminizing has had other applications. In the making of diffraction gratings speculum metal has usually been the base in which were cut the fine grooves so closely spaced that from ten thousand to twenty thousand lie side by side within the space of one inch. Light falling upon such a grating is reflected in such a way that the colours are assembled together and a spectrum is produced. Now gratings are being made from pyrex on which is deposited the chromium and aluminum layers and from rough usage tests to which some of them have been purposely subjected, it would seem that they stand up well and are likely to become standard equipment in the near future.

GENERAL INSTRUCTIONS FOR METEOR OBSERVING

By Peter M. Millman

PRACTICAL meteor observation, requiring as it does little or no expensive equipment, is the ideal field for the serious amateur astronomer. Because of the very nature of the problem, however, uniformity is often lacking in the methods of recording meteors or of planning observational programmes. It is proposed to outline here general methods for all types of meteor observation, designed to serve as a guide for both the amateur and the professional observer. In this outline an attempt has been made to retain flexibility so that the exact details of any programme may be varied to suit the immediate circumstances.

A Classification of Observational Data

Before any detailed scheme of observation can be decided upon it is essential to recognize all the information about meteors which may be recorded observationally. For convenience in reference this has been classified in Table I and for brevity the various sections will be referred to in this paper by the number in the Table. In general it will not be possible to cover this whole range in any one programme and so the observer must decide the sections upon which he will concentrate. In addition to his personal preference this selection will be governed by the limitations of the equipment, the number and experience of the observers available, and the desire to attain the most efficient co-operation with other observing stations. Some of the sections in Table I apply chiefly to photography and so cannot be covered by visual observation.

Table I—A Classification of Observational Data for Meteors

I Number

(1) The number of meteors appearing in a given area of the sky in a given time.

(2) The identification, where possible, of the radiant to which each meteor belongs.

(3) The time of the appearance of each meteor.

II Position

(4) The position of the meteor path in the sky, given either in relation to the stars or to the horizon system of co-ordinates.
(5) Any observed deviation from a great circle path.

III Brightness

(6) The average apparent stellar magnitude of the meteor.
(7) The positions of any maxima of intensity or bursts.
(8) The nature of any periodic or semi-periodic flickering.
(9) The distribution of intensity along the entire path.

IV Velocity

(10) The duration of the meteor for a given length of path or the average angular velocity.
(11) A change in velocity in the course of the visible path.

V Light

(12) Any marked colour of the meteor.
(13) A change of colour in the course of the visible path.
(14) The spectrum of the meteor while in flight.

VI Train

(15) The duration of the persistent train where this is present.
(16) The position of the strongest portion of the train.
(17) The distribution of luminosity in the train.
(18) The drift and change of form of the train.
(19) The rate of decrease of luminosity in the train.
(20) The colour of the train.
(21) The spectrum of the train.

VII Peculiarities

(22) A division of the meteor into two or more parts or the appearance of sparks.
(23) Any recognizable form or shape of the head, nebulous head, etc.
(24) The occurrence of detonations or other sounds associated with the meteor.
(25) Observations connected with the fall, or suspected fall, of a meteorite.

General Rules for Recording

There are certain essential facts which should always be recorded as a matter of course in all types of meteor observation. These are:—

(a) *The names of the observers.* For completeness of the record

both the first and last names should be given in full, as well as any titles such as Dr. or Prof. and the differentiation between Mrs. and Miss where ladies are taking part. Neglect of this simple rule has often led to errors in publication since, in a large programme of observation, it is inevitable that there will be many assisting who are not known personally to the one publishing the results.

(b) *The place of observation.* This is a very important matter for record but it is frequently neglected or given incompletely. Since meteors appear in our own atmosphere and are generally within one or two hundred miles of the observer the exact point of observation is important and hence it is a good rule to describe the observing station so that its position on the earth's surface can be determined to within 100 yds. if this should be found necessary. In a city this is fairly easy as the location with respect to streets can always be given. If the station is located in the country some distance from any good landmark it is a good plan to draw a little map showing enough of the surroundings so that the position may be plotted on a government survey map.

(c) *The date and time of the observations.* To avoid all possible ambiguity the date for night observations should always be recorded as a double date, even though the work is not carried on past midnight. Thus, any observations made on the evening of Apr. 20 would be recorded as on *Apr. 20-21, 1937.* This same date would apply to the morning hours of Apr. 21. This system is the only one where confusion in reducing records is entirely avoided. The possibility of error in the date is made even smaller if the day of the week is also given. The day previous to the night on which the observations are made is the one which should be recorded for example, observations commencing Monday evening, or even later in the night, should be recorded as made on *Monday night.* The watch or watches used at the observing stations should, wherever possible, be carefully checked against some standard time system both before and after the observations. Radio stations which have an hourly or half-hourly time signal are the most convenient to use for this purpose. The watch comparison should be recorded in the following form:—

1937, Apr. 20; $8^h\ 30^m\ 26^s$ watch time = $8^h\ 30^m\ 00^s$ p.m., E.S.T. Recording the watch as fast or slow, plus or minus, is open to

serious objection as a mistake in sign may easily occur and often the time at which the comparison was made is not stated. All meteor time records, whether in visual or photographic programmes, should be made in the time the watch reads and no reduction to standard time should be attempted during the observations. Where several watches are in use at one station they may be numbered for identification.

(d) *The condition of the sky.* Under this heading should be evaluated the three chief factors which affect the efficiency of the observations, namely, the moon, clouds or haze, and obstructions which hide a fraction of the visible hemisphere. A convenient system is to use a weather factor which is 10 for a perfectly clear, moonless night at a station with unobstructed view. A full moon reduces this to 5, a quarter moon to 8, or 7 if the region of the moon is observed. Clouds further reduce this factor by a percentage corresponding to the fraction of the field of view they cover or the fraction of the time they are present. If a portion of the field of view is hidden by a building or trees the factor must be reduced as for clouds and finally rounded off to the nearest integer. Since one observer cannot efficiently cover an area more than 80 to 90 degrees in diameter no reduction for buildings need be made unless they render his field of view less than this. If the observer is in doubt as to what weather factor to use it is better to write a simple description of the conditions under the headings given above.

Special Types of Observation

We must now deal more particularly with various types of meteor observation. As mentioned above, the following outline is flexible since different programmes will of necessity stress different points. Five general types of observation are considered.

A. *The Visual Observation of Specified Meteor Showers.*

A meteor shower occurs when the earth passes through a swarm of meteoric particles which are moving in an elliptical orbit about the sun. At such times a greater than average number of meteors is seen, those belonging to the shower seeming to radiate from a point among the stars known as the radiant. This apparent

radiation is an effect of perspective and the shower generally takes its name from the constellation in which the radiant is located. Meteors of any shower cannot be seen till the corresponding radiant is above the horizon but it is a mistaken idea to think that the shower meteors only appear in the constellation in which the radiant is located, for, once the radiant is above the horizon, the shower meteors may appear in any part of the sky. Other things being equal, they are more numerous the higher the radiant is above the horizon. Meteor observations carried out at the time of showers not only add greatly to our knowledge of the particular shower in question but serve as an excellent opportunity for the accumulation of general data concerning meteors since they are most numerous at these times. The most important annual showers for observers in the northern hemisphere are listed in Table II. The information in this table has been collected from several sources, among them the publications of Denning and Olivier.

TABLE II—THE CHIEF ANNUAL METEOR SHOWERS FOR THE NORTHERN HEMISPHERE

Shower	Approx. Radiant α	δ	Maximum Date	Hourly No. (all meteors)	Duration (in days)	Abbreviation
Quadrantids	232°	+52°	Jan. 3	20	4	Q
Lyrids	280	+37	Apr. 21	10	4	Y
Eta Aquarids	336	− 1	May 4	10	8	E
Delta Aquarids	340	−17	July 28	20	3	D
Perseids	47	+57	Aug. 12	50	25	P
Orionids	96	+15	Oct. 22	20	14	O
Leonids	152	+22	Nov. 16	20	14	L
Geminids	110	+33	Dec. 12	30	14	G

The first column of Table II gives the name of the shower, the next two the average position of the radiant on the maximum night. The fourth column lists the most likely time of maximum. This will vary by a day or more because of the shift introduced by leap year and uncertainties inherent in the shower itself. In general a

maximum is equally possible either in the early morning or the evening of the date given with slight preference in some cases for the evening. It is impossible to be more definite in a general table, and to be sure of observing the maximum of a shower the programme should be planned for the three or four nights near the maximum. It is probable that poor weather conditions will be encountered on at least one or two of these nights so that if only one or two nights can be spent in observing it is best to take full advantage of the first clear nights near the maximum date. The fifth column in the table gives, for all meteors, the average number per hour which are likely to be seen by a single observer on the night of the maximum. This figure is approximate only as in most cases it varies considerably from year to year. This is especially true of the Leonids which are very plentiful in some years. The last Leonid maximum occurred in 1931-32 and, while the figure in the table does not refer to these maximum years, it may well be that during the next fifteen years the Leonids will average rather lower than the value given. This shower is an important one to observe at any time however. The sixth column gives the duration of each shower in days, another very approximate figure, and the final column lists suggested abbreviations for the showers to be used on the record sheets.

The essential equipment for the visual observer consists of a watch, flashlight, pencils, and a record sheet mounted on a stiff back. The most comfortable and efficient arrangement for observing is to improvise a seat with a back inclined at an angle of about 45 degrees to the vertical. This enables one to observe from the horizon to the zenith without undue strain. If it is desired to concentrate on a region fairly near the zenith then the back should be inclined at a greater angle to the vertical. Records will be more accurate if the observer takes care to adopt a comfortable position at the beginning of each observation period. It is best to dim the flashlight in some way (red cloth may be fastened over the lens with elastic, for example) leaving just enough light so that the watch and record sheet can be clearly seen. This prevents the eye from becoming dazzled by too bright a light with the consequent loss of observing time.

A convenient form of record sheet is illustrated below:—

METEOR RECORD SHEET

Sheet No.....Group No..... Date.....
Watch Time Standard Time Place.....
..... = ... Weather Factor.....
..... = ...
..... = ... Observers.....
Recorder..... .....

No.	Watch Time h	m	s	Radiant	Mag.	Train Dur. (sec.)	Remarks
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....
.....	.....	.....	.....	.....	.....	.....	.....

The headings at the top of the sheet are self-explanatory in most cases. The group number is necessary only where several groups of observers are co-operating at the same station. In the first column of the record sheet is placed the serial number of the meteor. This number runs consecutively, commencing with 1 for the first meteor observed, and serves to identify each meteor either on the star maps or on other record sheets. The fifth column is for the identification of the radiant. For members of the showers listed in Table II the abbreviations given in the last column may be used. Meteors which do not belong to the particular shower being observed may be indicated by the letter N. The average stellar magnitude is placed in the next column and should be estimated by comparing the meteor with stars of known magnitude. The magnitude scale decreases by one unit for each increase in luminosity by a factor of 2.5. A standard sequence of stars of various magnitudes will generally be indicated on star maps used for meteor observation but for those lacking such material the following sequence may be used.

MAGNITUDE SEQUENCE

Faintest meteor definitely visible	mag.	5
The brightest stars in Cepheus, Hercules and the head of Hydra	"	3
The Pole star, the Belt of Orion and the brightest stars in the Big Dipper and Cassiopeia	"	2
Altair, Spica, Aldeberan	"	1
Vega, Capella, Arcturus	"	0
Sirius	"	$-1\frac{1}{2}$
Jupiter	"	-2
Venus	"	-4
The moon at the first or last quarter	"	-10
The full moon	"	-12
The sun	"	-27

The train duration is the length of time the train remains visible after the meteor has passed the corresponding point on the path. It should always be recorded in seconds, unless otherwise stated. A metronome kept ticking seconds or half-seconds throughout the period of observation has been found of great assistance in estimating train durations. Without any guide of this nature a novice is likely to think of a second as a much shorter period of time than it actually is and thus estimates the duration as too long. In the column under remarks should be noted any peculiarities of the meteor, including a pronounced colour when it is present. This latter can conveniently be recorded by the use of the following abbreviations:—

r	red	b	blue
o	orange	v	violet
y	yellow	w	white
g	green	rs	reddish, etc.

If the meteor is not plotted on a star map then the three-letter designation of the constellation in which it appears may be placed in the column for remarks.

One of the most satisfactory methods for recording the position of a meteor among the stars is to plot it on a star map. Since the path of a meteor generally approximates a great circle, and all great circles project as straight lines on the gnomonic projection, it is evident that gnomonic maps are the best to use in meteor

observing. On such maps the meteor paths may be plotted directly as straight lines. A set of 20 gnomonic maps by Prof. R. K. Young may be secured from the Dominion Observatory, Ottawa, Ont. These were originally published in 1915 and have been adopted by the American Meteor Society as the standard maps for their programmes of observation. In practice these maps have been found to include an inconveniently small area of the sky for some types of meteor observation and it is hoped soon to have available in Canada a second set of gnomonic maps where the area of the sky covered by each map will be three to four times as great. If gnomonic maps are not available any star maps covering a good area of the sky may be used. Plotting meteors in relation to a reticle, or metal framework of co-ordinates viewed against the sky from a fixed position, has been found a very efficient method in long systematic series of visual observations carried out by experienced observers. In this case meteors can be plotted with equal accuracy whether they happen to appear near bright stars or not. It is the writer's opinion, however, that in the case of the average programmes planned by the amateur, where observations are not carried out more or less continuously, the uncertainties in the exact form and orientation of a portable reticle will outweigh the advantages incident to its use.

The meteors should be plotted on the maps as lines, identified by the serial numbers placed beside them, the length of the line indicating the length of the visible path (see figure 1). Care should be taken not to exaggerate the path length when drawing it on the map as this is a common tendency among untrained observers. The direction of flight should be indicated by an arrowhead placed at the position of maximum intensity of luminosity. This point on the meteor trail should be estimated wherever possible. In the case of faint meteors where the position of the brightest point is uncertain the arrow-head may be placed at the centre of the trail. Any bright bursts or sudden increases of luminosity may be marked by short lines across the meteor trail as in the case of meteors 4 and 7 in the figure. The drift of a long enduring train may be indicated on the map as for meteor 2, or where it seems likely to remain visible for some time it is better to plot its shape and position at 30-second intervals on a separate sheet of paper.

It will be seen from the above that in general a visual observer will have a record sheet and a star map and where he is working alone will have to look after both sheets himself. When several are working together a better plan is to have one recorder with a watch to each group of five to six observers. The latter signal the appearance of each meteor by calling the word "time", at which the recorder makes a note of the time on the record sheet while the

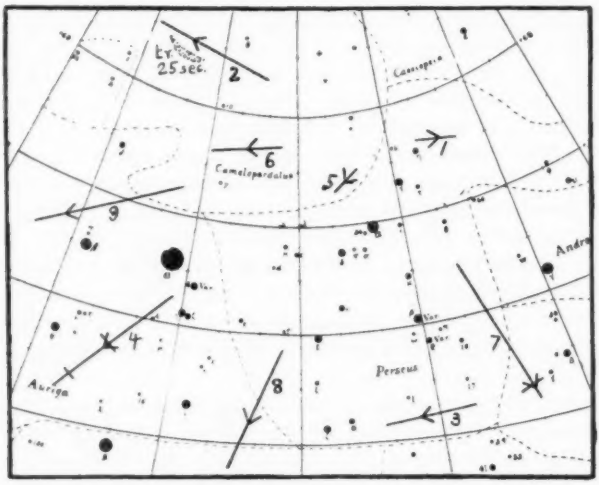

FIGURE 1. A portion of a Perseid map illustrating the plotting of eight Perseids and one Non-Perseid.

observer plots the meteor on the star map. The magnitude and other details concerning the meteor can then be given to the recorder to be filled in on the record sheet. A method which gives better information about magnitudes but which occupies a little more of the observer's time is to have each observer in the group supplied with a record sheet on which he may note the magnitude and other data for the meteors observed. In this case the chief duty of the recorder is as time keeper. Where a group of observers work together the serial numbers of the meteors refer to the group total. If the same meteor is observed by two or more members

of the group each will plot it on the star map and it will have the same serial number in each case. It is very important that each observer record either on the star map or the record sheet *the exact time at which he begins and ends the uninterrupted observing of the sky*. If recesses are taken during the period of the observations these should be noted.

What has already been said is of a fairly general nature and the exact procedure for any one programme may be considerably varied. The best rates (1)* can undoubtedly be determined by an observer who watches a certain area of the sky continuously for a fixed period of time. The limits of the area may be defined by the border of a star map or by a framework of wire viewed from a standard distance. But in this case the observer can make no records himself and though data can be given to a recorder it is not practicable to describe the position of the path in this way. It is usually preferable to sacrifice a little accuracy in (1) to increase the value of the rest of the data. It must also be remembered that continual close watching of the sky tires the eyes and the necessity of occasional reference to a map or chart introduces a change which rests the eyes and may partially make up for the time lost. When several stations are co-operating, as is generally the case in shower observations, the time (3) and the plotted path (4) are important as they are necessary for all computations of height. They should never be omitted for the bright meteors of negative magnitudes. An attempt should always be made to decide whether each meteor belongs to the shower being observed and this sometimes requires considerable judgment. It is not enough that the meteor path when projected back should pass near the radiant. It must be remembered that a long visible trail seldom occurs very near the radiant as here the meteors are moving almost head on towards the observer. In most shower observations particular attention should also be paid to magnitude and train observations, (6), (15) and (18). A good pair of binoculars is a very useful accessory in the observation of enduring trains as they can be thus followed much longer than with the naked eye. Data classified under the other numbers should be recorded wherever it is possible to obtain them visually.

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*The numbers refer to the classification of data given in Table I.

Observers in the same group should concentrate on different portions of the sky though it is best to record all meteors seen even if outside the assigned region. The only case where this rule does not hold is where accurate counts of meteors are being made over definitely restricted areas of the sky. If several groups are observing at the same station each group may be assigned a different region of the sky, as much as possible of the visible hemisphere being covered by the observers available. The most efficient co-operation between several stations is attained if the attention at each is concentrated on the sky in the general direction of the other stations. For example, when two stations are located north and south of each other the north station should concentrate on the southern sky and the south station on the northern sky. This will result in more meteors being observed in duplicate from both stations. To obtain reliable heights from visual observations stations should be separated by at least 30 miles. For photographic work distances as low as 10 miles will give good results. Valuable information concerning the probable number of meteors missed by an observer, and the magnitude of the various accidental and systematic errors entering into the records, may be obtained by having the observers at any station work in pairs. In this case each pair of observers should observe the same region of the sky but be separated from the others by 100 feet or more, thus making it possible to obtain several sets of independent records.

The hours at which observations of showers are carried out will be governed by the time at which the radiant rises. The Leonids, Orionids, and Eta Aquarids are only visible during the last half of the night. With the exception of the Geminids, which are best just after midnight, the other showers in Table II, though seen during the first part of the night, are more active well after midnight. When observations at several stations are undertaken on the same night an attempt should be made to have these carried out during the same intervals of time.

B. *General Visual Observation.*

This type of observation is carried out in much the same way as that described above, with this difference, that it is planned for any clear moonless night rather than for the periods of well-known

meteor showers. It is not quite so interesting for the beginner as fewer meteors are seen but it provides very necessary and important information for a better understanding of the system of meteors and interstellar matter. The average number of meteors seen by a single observer on a moonless night during the first six months of the year is about five per hour and roughly double this number are observed during the last half of the year. Meteors are generally about twice as numerous during the last half of the night as they are during the first half, since in the former case we are on the front side of the earth as it journeys round the sun.

In most cases of general observation there is not much chance of another party observing meteors nearby and, unless it is desired to concentrate on a study of radiants, (4) is less important and may be omitted in favour of paying more attention to (6), (7), (12), (15), and any other points that can be noted. Where not co-operating with another station the exact determination of time (3) is not so necessary and (2) is usually indeterminate. Visual estimates of velocity (10) must generally be restricted to qualitative remarks such as "fast" or "slow" as any actual estimate of duration is likely to be very uncertain. In the case of an exceptionally brilliant meteor, magnitude -2 or brighter, all data should be noted including a plot of the path and the exact time of appearance as in this case there is a possibility of observations at other stations being made by chance.

C. *The Chance Observation of Bright Meteors or Fireballs.*

We must now consider the bright meteors which are seen by chance when no scheduled observations are being undertaken. Any meteor brighter than magnitude -2, or the average brightness of Jupiter, falls into this class. These objects are bright enough to attract the attention of the casual observer and in many cases several reports from different localities are received at an observatory or other headquarters for meteor study. These very bright meteors always come unheralded and our knowledge of them rests almost entirely upon the chance observations of laymen. For this reason a complete report made by a careful observer is of great value in the reductions and one should never fail to write down all observed details as soon as possible after the appearance of such

meteors. In making the record the classification of Table I may be used to make sure that no important detail has been omitted and the four general points under *a*, *b*, *c*, and *d* should not be forgotten. The most satisfactory way of noting the path is a plot of the meteor among the stars, no matter how roughly this is drawn. This is sometimes impossible because of twilight or because the observer is unfamiliar with the constellations. In that case the position of the path should be given by estimating its altitude above the horizon (altitude of horizon, 0°; of zenith, 90°), and its direction with respect to the four cardinal points of the compass. The slope of the path, that is the inclination to the vertical, should also be given. One good way to determine altitude (or any other angle) is to take two rulers or straight sticks and hold them together directing one to the place in the sky where the meteor appeared while the other is pointed to the horizon immediately below. If the rulers are now held firmly together in this position the angle between them can be drawn on a sheet of paper. The same can be done for the point of disappearance of the meteor. Altitudes estimated directly are generally too great by 5 to 10 degrees.

The brighter the meteor the more chance there is of a train and the peculiarities listed under VI and VII in Table I and so these features should be carefully watched for. In particular, when detonations or sounds are heard, a careful estimate should be made of the interval between the appearance of the fireball and the arrival of the sound. If there is a total absence of a persistent train this fact should be noted in the report. Information about a spectacular meteor should always be sent to some headquarters where meteors are studied as quickly as possible as in some cases it is advisable to insert requests for additional observations in the newspapers.

D. *Telescopic Meteor Observation.*

This type of observation is concerned with the same data that have been mentioned in connection with the programmes for naked eye work, but with the help of the telescope we can extend our investigation down to the faint meteors of magnitude 10 or fainter. The best type of instrument to use is a refractor between one and

six inches in aperture, equipped with a very low-power eyepiece which covers a wide field of view. If x is the lowest magnification which may be used, while still utilizing the full diameter of the objective, then approximately $x = 4a$, where a is the telescope aperture in inches. Thus the lowest power suitable for a two-inch telescope is 8X, for a three-inch is 12X. As a rule the closer this power is approached the more efficient the telescope will be for meteor work. Binoculars with 2-inch objectives and power 8X or 6X binoculars with 1.5-inch objectives are excellent for meteor observation as these instruments usually have a wide field of view. A convenient method for determining the diameter of the field of view is to turn the telescope to the equator, keep it in a fixed position, and count the number of seconds required for a star to pass centrally through the field. This number divided by 240 then gives the diameter of the field in degrees = d say. The product of the real field, d, by the magnification, m, may be called the apparent field = dm. For efficiency in meteor observation the diameter of the apparent field of the telescope should be at least 40 degrees. This is best attained with a negative (Huygens) eyepiece. In extreme cases, by a careful selection of eyepieces it is possible to have an apparent field 50 degrees or even 60 degrees in diameter, though in the latter case there may be loss of light at the edge of the field. If we assign the arbitrary value 100 to the efficiency E of a telescope where m = x and the diameter of the apparent field is just over 50 degrees, then a convenient expression for the relative efficiency of telescopes of any given aperture when used in meteor observation is

$$E = 0.6\ (ad)^2$$

where a is given in inches, d in degrees, and it is assumed that m is greater than or equal to x and that there is no appreciable loss of light at the edge of the field. The meteor observer should, if at all possible, use an instrument with an efficiency of 50 or more. The choice of aperture will depend upon what meteor magnitudes it is desired to observe. The greater the aperture the fainter will be the mean magnitude of the meteors recorded. With an efficient instrument the average rate for telescopic meteors should be

between 2 and 4 per hour with considerably higher rates at the time of showers.

The same type of record sheet as suggested for the observations with the naked eye may be used, but in addition to the other information the aperture, magnification, and real diameter of the field of the instrument should be placed at the top of the sheet. In most telescopic work the accurate time of each meteor is not very important. The magnitude should be estimated by comparison with stars seen with the naked eye as in the other programmes. These can later be corrected in the reduction for the light-gathering power of the telescope. For example, the faintest meteor clearly seen in the telescope will be recorded as of the 5th magnitude. If the meteor is compared to stars that happen to be in the field of view at the time its brightness should *never be recorded as a magnitude* but only as brighter than, equal to, or fainter than the stars in question. This will avoid confusion in the magnitude system. Attempts should be made to estimate the duration of telescopic meteors as accurately as possible.

When telescopic observations are made at the time of meteor showers it is best to turn the telescope towards the radiant, and the meteors observed may then be plotted on a suitable map of the faint stars located near the radiant. In general telescopic observations the instrument should be fixed in a stationary position directed to the zenith or to one of the four cardinal points of the compass at an altitude of 45 degrees. The meteors can then be plotted in relation to the field of the telescope, represented by a circle on a sheet of paper, or the length of trail may be given and the direction of flight recorded by giving its position angle counted from the direction up (12.00 o'clock position) around counter-clockwise to 360 degrees. A small wire reticle inserted in the focal plane of the eyepiece will make the observation of the meteor's path more accurate. If two stations are co-operating in a height determination of telescopic meteors they should be located from one to five miles apart and the telescopes at either end of the base line inclined towards each other so that they cover the same region of the atmosphere 50 to 60 miles above the surface of the earth. In this case the accurate timing and plotting of the meteors is essential.

E. *Photographic Meteor Observation.*

With the photographic technique available at the present time only the brighter meteors can be studied since it is not often possible to photograph a meteor fainter than magnitude 0. For this reason photography, as we know it at present, will never replace the visual work, but it does make possible the investigation of sections (8), (9), (11), (14), (19), and (21) in Table I which are almost impossible to study visually. In addition to this it provides data under most of the other headings which are much more accurate than visual observations can hope to be. Meteor photography has been rather neglected in the past and it is hoped that in the future amateur photographers will realize their opportunity here for materially aiding the advancement of astronomy.

The camera used should have a fast lens, preferably f/4.5 or better, though many meteor photographs have been taken with f/6.3 lenses. The lens should always be used at its widest aperture and the camera fixed in a stationary position during each exposure. The shutter is set to time and the lens opened at the beginning of the exposure and closed at the end. Fast panchromatic plate or film is most efficient for direct photography and exposures of one hour may generally be made without undue sky fog. If near city lights or if there is a bright moon this exposure time should be shortened to 30 minutes or even 15 minutes for very fast lenses. The stars will appear on the photographs as trails which approximate arcs of circles centered at the celestial pole. A meteor will appear as a straight line of varying intensity, crossing the plate at any angle. For all astronomical work the camera is used at infinity focus and if one is not certain of this a series of focus tests may be necessary. If it is desired to photograph meteor spectra a prism with a refracting angle of about 30 degrees should be firmly fixed in a position of minimum deviation just in front of the lens. A rotating shutter operated in front of the lens will enable the angular velocity of the meteor to be determined.

At the time of meteor showers the best field for meteor photography is that near the radiant. For general programmes almost any region of the sky that is not too near the horizon is equally favourable. In addition to the general information under a, b, c, and d the most important points to record in photographic pro-

grammes are the exact times of the beginning and end of each exposure and the times of any bright meteors which happen to cross the field of the camera during the exposure. On shower nights one may expect, on the average, to secure one meteor photograph for each five hours exposure. For general programmes the average expectancy is one meteor photograph for each twenty hours exposure time. The above figures apply to direct photography. In spectrophotography the average exposure per meteor photographed is very much longer.

Lack of space prevents the subject of meteor photography being more fully dealt with here but for further details the reader is referred to the chapter commencing on page 544 of "Amateur Telescope Making, Advanced", a book published by the Scientific American Publishing Co.

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MERCURY IN 1936

By Walter H. Haas

ALTHOUGH the planet Mercury, because of its proximity to the sun's place in the sky, is probably the most difficult to observe of all the planets whose surface detail is investigated, it has been studied in recent years by different observers. This article contains the results obtained in 1936 by E. Martz and the author, both planetary observers of the American Amateur Astronomical Association. Martz made five drawings in Jamaica, B.W.I., with Professor William H. Pickering, using a 6-inch reflector, and a 12.5-inch reflector; the author made eighteen drawings at Mount Union College in Alliance, Ohio, using a 10-inch refractor. The period covered by the observation is that from April 23 to August 1.

Mercury in its apparent motions and general telescopic appearances (phases, difficulty of detail, etc.) is similar to Venus; and it should be interesting for planetary observers to compare these objects on the occasions when they are near each other. The author attempted such a comparison just before sunset on July 31 and in the early afternoon of the next day. He found that there was more contrast on Mercury than on Venus, Mercury probably showing almost as much contrast as some portions of Mars at some seasons, and that Mercury was much redder than Venus. During his actual observations of Mercury, all but two of which were made in the twilight or dawn, the author found that Mercurian detail was almost always very difficult but came out very dark by glimpses. How conspicuous this detail might have been under good conditions was difficult to ascertain. Martz considered the dark marks of Mercury much darker than those of Venus and noted that they contrasted more strongly with the ball of the planet. Although the reddish hue of the planet was intensified by haze, the author did see the disc of Mercury as very red; but Martz saw this disc as orange or yellow.

The cusps of the planet appeared to differ from the ball both in colour and intensity, a phenomenon also seen on Venus by some observers. The cusps also had dark borders, suggesting the polar cap-bands of Mars. The north cusp was dimmer than the ball of

the planet, though darker than the dark areas, and had a wide, not very-dark border. These two marks were the two most consistently visible on the planet; James Weldy, student at Mount Union College confirmed them on April 24, although he could see nothing else on the planet. Weldy had had no previous experience in planetary observations. The south cusp was twice recorded as outstandingly bright and white by Martz in the last days of April. Such was also its appearance to the author from June 29 to July 31, though he also sometimes recorded it as dimmer than the ball in April and May.

Martz and the author had totally different conceptions of the nature of the dark detail. Martz showed it as consisting of darkened areas, whose general appearance may be compared to the Martian or lunar maria. The author showed it as consisting of rather narrow arc-marks. These differences between Martz and the author extended to their Venus work and are characteristic of personal difference in delineations of planetary detail. The author saw the dark marks on the limb and terminator as darker than those centrally placed on both this planet and on Venus. The most interesting dark mark was a triangular area on the west limb near the equator when the disc is full. This mark was distinctly shown on the terminator by both Martz and the author from May 6 to May 20, on almost all drawings; it was probably brought into view by libration.

A few bright spots were seen on the limb by the author and might have been caused by clouds; they were small and white. Better evidence for a Mercurian atmosphere, probably a thin one, can be found in a change in the south cusp-cap between mid-May and late June, and in the dimness and grayness of the terminator. This phenomenon, occasionally seen or suspected by both observers, suggests a twilight effect of some sort.

We must realize, however, that, under the extremely trying conditions of observation, errors in drawing are apt to be large; and we must be careful before declaring any mark on Mercury objective. The author accordingly, with the purpose of testing the reliability of his Mercurian detail, made six drawings of the planet Mars in October and November, 1936, when the diameter of Mars was only 4″ of arc. The forty-seven marks seen were

checked against M. Antoniadi's chart of the planet, and it was found that only half of the marks seen were sufficiently exact representations of detail to be certainly identified with known marks. The very small size of the disc and exceptionally poor seeing made errors on Mars worse than those on Mercury. A better test is to compare the author's marks, shown on a rough map constructed from drawings, with planispheres of Mercury by such competent observers as Schiaparelli, Lowell, Jarry-Delosges, Antoniadi, and the Mercury and Venus observers of the B.A.A. The author compared his rough map with photographs of these planispheres in the October 1936 issue of the Journal of the *British Astronomical Association*. Of the author's twenty-two marks, four were confirmed; and six were partially confirmed. This is satisfactory agreement if we consider all the difficulties of observing Mercury.

The author's drawings indicated that Mercury rotates in 88 days or always keeps the same face sunward, a fact already well established.

VENUS IN 1936

By Walter H. Haas

PERHAPS the best way to describe the telescopic appearance of the planet Venus is to say that it is a burnished globe of metal, a very little tarnished in places. Vague tarnishings on a burnished background are inconspicuous, and not one mark on Venus is known to be permanent beyond question. With the realization of the difficulties of observing Venus, of the impossibility of saying anything about the planet without contradicting some competent observer, and of the fact that long observations by skilled observers often lead only to controversy, the author herein presents the results of his own observations of Venus, basing them upon sixty-one drawings between October 31, 1935 and November 11, 1936. The author worked at Mount Union College in Alliance, Ohio, with a 10-inch refractor. Venus was at superior conjunction about the first of July. From March to November, the disc was sensibly full; and all work in this period was done by day.

The author's impression of the ball of Venus is one of arc-like marks, usually running toward the center of the planet from the edges. The arcs are very vague, very narrow, usually pointed at their ends, usually concave northward or southward and are often seen in pairs.

White spots were seen, though only on the limb and terminator, and were strongly suggestive of clouds. Some of the spots seen in January and February were very white and very small and looked as though they were actually elevated above the general surface of the planet. Not all white spots are clouds of this sort, however; and some of them are regions permanently bright and white, which are perhaps overlaid by permanent fogs or clouds of some sort.

The cusp-caps of Venus are controversial marks seen by some and not seen by others. The caps were sometimes brighter than the ball and sometimes dimmer, but the amount of contrast between them and the ball was slight. We shall mention seasonal variations in these cusp-caps later. As distinct as the cusps were their borders or "collars"—rather prominent marks for Venus. A short series of observations of the naked-eye moon adduced this result: "Although there can be seen on the moon at certain phases cusp-dimming and even cusp-cap effects, possibly caused by objective contrasts on the moon, the lunar cusp-effects are less objective than those of Venus, in particular lacking definite borders".

The author came to the conclusion that Venus always keeps the same face sunward, in which respect he confirmed the 225-day rotation period of Schiaparelli and Lowell. It ought to be stated, however, that many competent observers favour much shorter periods, periods ranging from a little less than a terrestial day to forty days. The author's own opinion is based upon a study of his drawings. A certain arc on the west limb was seen from February to November, and many other arcs (and some bright spots) can be identified on drawings months apart. Venus was not changeless by any means, but there was no steady drift of detail such as rotation should produce. The fullness of the disc partially compensated for its small size, since no allowance had to be made for a shifting terminator. Week after week the familiar marks remained in the familiar places.

The author is also of the opinion that the dark marks seen are

surface features, for they were too permanent and unchanging for clouds. The extreme vagueness of these marks is due to the thick atmosphere enveloping Venus, that all but blots them out. It must be conceded, however, that an arc is a strange kind of land or sea detail and that some authorities consider all Venusian marks clouds.

The author's third conclusion is that the inclination of the axis of Venus to the plane of the planet's orbit is from 75 degrees to 85 degrees. That the axis does not deviate much from perpendicularity was shown by the similar size of the cusp-areas at all times and by the absence of any general north-and-south trend of the marks. If the effects of foreshortening do make the detecting of shifts in the cusp-areas difficult, general shifts should have been easily seen in the center of the ball; and the amount of these shifts while Venus made a complete revolution around the sun, as she did from March to November, would be twice the difference between the inclination of the axis and ninety degrees. An axis inclined at an angle of sixty-five degrees would necessitate all central marks shifting through an arc of fifty degrees. No such shift could be detected. The actual values mentioned (75° to 85°) are based upon a consideration of several variations (to be mentioned later).

Of the existence of clouds on Venus there can be no doubt whatever. The white limb spots already mentioned; numerous distortions of detail and temporary disappearances of marks, beyond errors of observation; the fact that detail was vaguer in the "winter" hemisphere than in the summer hemisphere of the planet, a phenomenon compatible with the cloudiness of our terrestrial winter skies; the vagueness of all marks near the center of the disc when the planet is full and exposed to the perpendicular rays of the sun and hence favourable for the formation of clouds—all these things certainly look like manifestations of clouds.

The study of changes on Venus is difficult because it is not easy to ascertain the exact extent of errors of observation; and we must limit ourselves to changes reasonably well established even at the cost of missing many rapid changes of short duration. The author found three types of changes: Temporary and irregular, periodic, and seasonal (period 225 days or the Venusian year).

The temporary changes were hard to distinguish from errors of

observation. They usually consisted of the disappearance of vagueness or abnormal aspect of some mark.

The periodic changes consisted to a large extent of changes in the darkness of arcs. The most common period of variation was between two and three months. Some of the abnormal appearances already mentioned recurred with periods of eighteen days to three months. A mark on the west limb near the equator was alternately long and short with a period of only ten days from April to August.

In investigating seasonal changes only the May-to-November drawings were usable. In late May, June, and July, the south hemisphere was the dominant hemisphere, the south cusp being brighter than the ball and the south one dimmer. Several southern arcs and spots were conspicuous for Venus, but the only northern arcs consistently seen were vague. At heliocentric longitude 140° a change occurred. The south cusp was now like the ball; the north a shade brighter. The northern arcs were more conspicuous, and this revival of the northern hemisphere seemed to affect the equatorial regions. The southern arcs were in general vague. Some periodic changes were apparently unaffected by seasonal variations; however, of three arcs, two southern and one northern, the two southern varied in harmony with each other, while the northern was often in exactly opposite phase of variation. As on Mars, there is much more detail in the southern hemisphere than in the northern.

Mount Union College,
Alliance, Ohio.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

Meteor Spectra—List IV

As in other years a list is here given of all meteor spectra which, to the knowledge of the writer, were photographed in 1936. It is earnestly hoped that anyone knowing of additional meteor spectra secured in 1936 will communicate with the writer at the Dunlap Observatory, Richmond Hill, Ont.

Photographic Meteor Spectra—List IV

Spectrum	*Date*	*Place*
XL	Aug. 1936	Apscheron Peninsula, U.S.S.R.
XLI	Aug. 1936	Apscheron Peninsula, U.S.S.R.
XLII	Oct. 19, 1936	Upsala, Sweden.

The numeral in the first column of the list is for purposes of identification and has been applied consecutively commencing with the first spectrum photographed in 1897. Spectra XL and XLI were photographed by the meteor expedition under V. V. Fedynski, mentioned in the last number of the Journal. They are described as weak, showing from 4 to 6 lines. Apparently both contain iron lines while one has in addition the H and K lines of ionized calcium.

Spectrum XLII was photographed by chance with the Zeiss-Heyde astrograph (aperture 15 cm., focal length 150 cm.) at the Upsala Observatory. The telescope was being used with a prism of 9.7 degrees refracting angle giving a dispersion of about 270 au/mm in the region $H\gamma$ to $H\epsilon$. The meteor appeared at $20^h\ 50^m$ G.C.T. Oct. 19, 1936, and was observed by Å. Wallenquist as unusually bright with a persistent train which remained visible for 5 minutes. A note on this spectrum has ben published by C. Schalén in Populär Astronomisk Tidskrift, vol. 18, p. 74, 1937, and an excellent detailed study of the spectrum by C. Schalén and G. Wernberg appears in the Arkiv för Mathematik, Astronomi och Fysik, vol. 25 A, no. 26, 1937. This also appears as Upsala Observatory Reprint No. 68.

Spectrum XLII consists of 10 lines, the two brightest being identified with the H and K lines of ionized calcium. The eight

other lines are apparently all blends of the iron lines though the elements Cr, Mn, Mg, and Ni may possibly contribute some of the intensity. The spectrum is too weak to separate these other elements from the iron. The presence of the H and K lines places the spectrum in Type Y and though the iron lines are too weak for detailed study the authors conclude that, owing to the great strength of the ionized calcium, the effective temperature of the meteor vapor must have been at least 3000°A.

The intensity of the stronger lines in the spectrum were studied by means of a recording microphotometer. Fortunately the plate could be calibrated for this purpose since a previous exposure taken with a grating crossed with the prism had been made. It was noted that the total intensity of the spectrum increased fairly suddenly at a point about half way along the photographed path. The ratios of the intensities of the two ionized calcium lines (H/K) and of the iron group at λ3850 to the K line (3850/K) were determined at 48 points along the meteor's path. H/K was fairly constant and averaged 0.48, in good agreement with the theoretical value 0.50. The ratio 3850/K decreased rather abruptly near the point where the meteor brightened from an average of 0.47 for the first part of the trail to an average of 0.14 for the last part of the trail. This sudden increase in the relative intensity of the calcium lines to three times their former value is an observation of great interest. It is undoubtedly closely associated with the phenomenon of "bursts" or sudden increases of light along the meteor's path but a complete discussion of this subject must await additional observational evidence. This paper by Schalén and Wernberg is an example of the valuable information that can be derived from a thorough study of even a relatively faint meteor spectrum.

In this connection mention should be made of another recent paper which gives a tentative identification of the lines in Spectrum XXXII. It appears in *Popular Astronomy*, vol. 45, p. 214, 1937, and is by John S. Hopkins. Ten lines have been measured and are identified with Ca^+, Ca, Mn, Mg, Sr, Mo, Na, Li and Co. To the writer of these notes the complete absence of iron in this spectrum seems rather surprising but further discussion is reserved till a more complete study is available. P. M. M.

REVIEW OF PUBLICATIONS

A Star Atlas and Reference Handbook, by Arthur P. Norton. Sixth Edition, 84 + xxi pp. + maps (about 100 pp.) 8½ × 11 ins. London, Gall and Inglis; Boston, Eastern Science Supply Co., 1937.

To most professional and many amateur observers Norton's Atlas needs no introduction. For this new edition much of the text has been revised, but the maps and general subject matter remain in their convenient, pleasing, and familiar form.

For those not acquainted with this book, it should be noted that it falls into two distinct parts—a star atlas and a reference handbook. The atlas consists of eight double page star maps; as each covers about one-fifth of the sky, there is a generous overlapping of the fields. The maps show nearly 8000 stars, including almost all stars to magnitude 6.2, and about 600 nebulae and clusters. The International Astronomical Union constellation boundaries, the ecliptic, galactic equator, and Milky Way are also marked. Symbols show the brightness of the stars to the nearest half magnitude. The scale of these maps is about 10° = 32 mm. The polar maps cover from the poles to 50° declination; each of the equatorial maps includes five hours of right ascension, and extends from −60° to +60°. Each map is accompanied by descriptive lists of the most notable double and variable stars, and clusters and nebulae. Two convenient galactic star charts are also given, covering the region between +50° and −50° galactic latitude, with superposed equatorial reference curves.

The reference handbook tabulates much useful information, such as lists of astronomical societies, publications, nomenclature, pronunciation and conversion factors for physical and astronomical quantities. It also includes an excellent glossary, defining and describing astronomical terms. Other sections summarise information on spectroscopy, the sun, moon, planets and stars. Two observational chapters deal with hints on observing, and details of the care of telescopes.

Anyone interested in learning the constellations, for his own pleasure or for constructive observational programs, will find this book of great use. F. S. H.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Doubly Rewarded

A friend who has some knowledge of the sky relates the two most interesting incidents of an astronomical nature which he has experienced. The first occurred on Sunday evening, February 9, 1913. With his wife he motored about three miles to a church in the middle of Toronto and parked his car on the street. After the service they returned home and his wife realized that she had lost a valued ring. On thinking over her movements for the last few hours she recalled that when she got out of the car she removed her gloves. Had the ring been dropped then? Back to the church they went and carefully examined the snow-covered ground where the car had been parked. The ring was found; and just as the search was ended there appeared in the sky overhead that most remarkable of all meteoric displays, when hundreds of bright bodies moved in regular formation across the sky, coming from the north-west and disappearing in the south-east. The display was described by the present writer in this Journal for 1913.

The second incident was a recent visit to a Planetarium in the United States, when he was thrilled with what he saw, as is everyone who goes to one of these admirable institutions. He is not the writer of the Note which follows.

A Visit to the Hayden Planetarium, New York (Contributed)

What a magnificent toy for an astronomer is a planetarium. I hope Santa will bring me one for Christmas. Next to being a locomotive engineer, I should like to be the man who runs the planetarium. He pulls a lever, or touches a button, and his toy universe obeys.

Human beings have, deep in their consciousness (whether they are aware of it or not) a reverence, a religion, a superstition,—call it what you will—which becomes *awe* when they gaze at a star-lit sky.

It was this deep sense of awe that caused the hush which settled upon the audience when the dome in the planetarium suddenly blazed with stars. In the darkness of the auditorium it had been as if we

waited for the creation. "Let there be light,—and there was light!" We were allowed a few moments of silence, to take it all in.

There, were all the familiar stars, the constellations, and planets. How much you see in a planetarium depends on how much you have seen in the past. The sky in the planetarium is familiar to you because the *real* sky is known through your years of looking at it. Magnificent as is the illusion of the planetarium, it serves to bring to us anew the marvel of the actual sky, with its depth and brilliance. The Pleiades alone, on a clear dark night, for beauty could outweigh millions of planetariums; and the director of the planetarium would be the first to acknowledge this fact. But again, what a magnificent instrument it is for a lecturer on astronomy. A magic lantern fit for Aladdin, a motion picture projector, a musical instrument, the mechanism of a great telescope, and I do not know how many other wonders are encased in the fascinating instrument seen under the centre of the dome.

As the seventy-five foot auditorium grows dark it seemingly expands into the wide space of Central Park, and on the horizon all around is seen the evening sky-line of New York.

Soft music is being played. The lecturer makes a poetic reference to the music of the spheres, and the crowd gazes at the starry dome in quiet meditation. In a low voice the lecturer begins his explanation. One realizes how much the unreal sky has become real when apparently across the firmament flashes a giant meteor! It dashes to the Pole Star and comes to a stop, and we then discover it to be a flashlight pointer, in the shape of an arrow, held in the hand of the lecturer and projected on the dome.

The darting of this arrow of light from star to star and from horizon to horizon is perhaps more startling than the lecturer realizes. It may be intentional however, and certainly brings the audience back to New York.—*F.T.S.*

Moon's Features—Volcanic or Meteoric?

The question whether the moon's surface features are due to volcanic or meteoric action is now being discussed again, and I have pleasure in reproducing the following discussion of the problem by E. G. Hogg in "The Press", Christchurch, N.Z.:

1. *Volcanic Action*

It may at once be said that the origin of these marked features of the moon is still a matter of dispute. According to the earliest theory in the field they correspond to the volcanoes with which the earth's surface is studded. There is reason to think that far back in the geological past volcanic action was much more intense on the earth than at present, and it is likely that craters may have existed which were on a grander scale than those we can now study. Changes of level and denudation have destroyed much of the evidence as to their magnitude, but it is improbable that even at their best they rivalled in size those possessed by the moon. We must, however, bear in mind that the force of gravitation at the surface of the moon is only one-sixth of that at the earth's surface, and hence with the same propelling force a body on the moon would be hurled six times as high as on the earth, and furthermore, its upward and outward flight would not be impeded by any resisting atmosphere. Still, when we have made all allowance for these two factors we can only accept the volcanic origin of the ring-walled plains on the assumption that volcanic activity on the moon must have been on a far greater scale than it ever was on the earth, and there appears to be no adequate grounds for this assumption.

It is generally held that the moon was once part and parcel of the earth, the material of the moon having been torn off in one or more violent oscillations of the compound body; if this was the case, it is probable that the moon is composed of matter which formed the external layers of the earth. Now there is good reason to think that the radio-active minerals which the earth possesses are present mainly on its outermost strata, and we should in consequence expect that the moon, formed from the outer terrestrial layers, started its existence with a good supply of radio-active matter. This matter slowly disintegrates, giving off heat, and it is possible that this heat accumulating in the interior may have produced surface explosions of sufficient magnitude to produce the craters now visible on the lunar surface. In this connection we may notice that, on account of the presence of radio-active elements within the earth, the temperature of our globe may still be rising, not falling, as is generally supposed.

2. *Meteoritic Bombardment*

We now pass on to the theory which supposes that the ring-walled structures are the result of bombardment of the moon by meteorites when its crust was still in a plastic state. These bodies reaching the moon from outside may have had their origin within the solar system or may, as Schiaparelli and others have advocated, come from inter-stellar space. Modern opinion inclines to the belief that meteorites are in general true members of the solar system and in this case the velocities with which they would strike the moon would be between eight and 44 miles a second. When we recall that the moon is

now and must have been at an early stage of its existence devoid of any protecting atmospheric envelope to reduce the speed of the impinging meteorites, it is clear that one of these bodies moving at the rate of, say, 30 miles a second possessed an amount of kinetic energy capable of producing catastrophic results when impact with the crust of the moon took place. If the meteorite came from beyond the solar system it might strike the moon with a speed of many hundreds of miles a second with proportionately disastrous effects.

This theory has been objected to on the ground that the earth shows no signs of having been subjected to any bombardment comparable in violence with that suffered by the moon. This is quite true, but it must be remembered that the earth's atmosphere is capable of so reducing the speed of a meteorite entering it that in general the collision does not cause any serious disruption of the ground. The effects of very violent impacts in past geological ages would be speedily smoothed out by the denuding and other agencies which affect the earth's surface. It seems probable to the present writer that meteorite bombardment was far more violent in distant geological times than at present. In the case of the earth the crustal disturbances so caused are likely to have been completely obliterated, while those occurring on the moon have been preserved because of the absence of the agents necessary to modify the lunar landscape. The breaches so often to be found in the ramparts of the craters may be accounted for by the impact of meteorites of later date. There are serious difficulties confronting either of the theories outlined here, but it would appear that present opinion seems to lean towards the origin of the major features of the moon's surface by the impact of meteorites at a very distant date in the past; it is to be hoped that the committee now studying this problem will decide between the two theories or show that both volcanic action and meteoritic collision have taken part in evolving the moon's present aspect.

The Retrograding Phoebe

A correspondent sends the following clever little poem, inspired by the retrograde motion of Phoebe, the ninth satellite of Saturn. It is taken from a book entitled "After All" by Clarence Day and will be enjoyed by our readers.

Phoebe, Phoebe, whirling high
In our neatly plotted sky,
Listen, Phoebe, to my lay:
Won't you whirl the other way?

All the other stars are good
And revolve the way they should.
You alone, of that bright throng,
Will persist in going wrong.

Never mind what God has said;
We have made a law instead.
Have you never heard of this
Neb-u-lar Hy-poth-e-sis?

It prescribes, in terms exact,
Just how every star should act.
Tells each little satellite
Where to go and whirl at night.

Disobedience incurs
Anger of astronomers,
Who—you mustn't think it odd—
Are more finicky than God.

So, my dear, you'd better change.
Really, we can't rearrange
Every chart from Mars to Hebe
Just to fit a chit like Phoebe.

C. A. C.

REPORT OF VARIABLE STAR AND NOVA SEARCH OBSERVING SECTION
TORONTO CENTRE, FOR MAY, 1937

Nova Search								Variable Stars			
Area	Mag. faintest star 8	7	6	5	4	3	No. Searches	Variable	Mag. Estimates	No.	Remarks
Mr. Neil McNabb.											
8			3				3	R. Leonis	6.9,7.2,7.5,7.6	4	Rising
58		10	3				13	R. Urs. Maj.	8.0,7.7,8.2	3	
72	6	2	3				11	R. Cor. Bor.	6.8,6.4,6.4,6.4		
									6.4,6.0,6.0	7	
Miss R. J. Northcott											
71		4		3			7	R. Leonis	6.3,6.5,6.9,6.5		
9				2			2		7.2,7.5	6	Rising
Mr. Bert Topham											
75	1	1					2	R. Leonis	6.5,7.2	2	Rising
16	1	1					2	R. Urs. Maj.	8.0,8.0	2	
								U. Herc.	10.3,9.6	2	
								T. Aquarius	10.3	1	
								W. Herc.	13, 13, 13	3	

F. SHIRLEY PATTERSON.

MEETINGS OF THE SOCIETY

AT VANCOUVER

March 9, 1937.—The 46th regular meeting was held in the Science Building, U.B.C., on March 9th, Mr. H. P. Newton presiding. Minutes of the previous meeting were read and adopted. The Chairman briefly discussed celestial phenomena for the month and then introduced Dr. F. Dickson of the University of British Columbia, whose topic was Life on our Planet. Stating his belief that the aspect of his subject which would bring biology nearest to astronomy would be that dealing with the origin of life, Dr. Dickson briefly pictured the physical conditions existing at early epochs and their evolution to a stage favourable to life. Turning then to the elements composing living matter, he pointed out that all these elements are present in the inorganic world; that the basic living matter—protoplasm—is built up from proteins (the most complex chemical compounds known), carbohydrates, fats, inorganic salts and water. The chemical and energy transformations that occur in protoplasm constitute life, the ultimate source of energy being the sun. Green plants have the power of utilizing the solar radiation to convert carbon dioxide and water into sugar from which the more complex compounds, as proteins and fats, are synthesized, the oxidation of which, within living organisms, releases the energy for life processes. Thus simple elements and energy are shown to make the "vital force" once termed mysterious. Protoplasm is organized into cells, which are the units of all living organisms. They consist of the main body of the cell and a nucleus which contains the complex material "chromatin" which appears to be vitally concerned with the functioning of life in the cell.

Biologists generally believe that living matter developed from non-living matter at some period in the earth's history, and some have suggested steps in the supposed process of development. Sir Ray Lankester, Mereschkowsky and Minchin were among those prominent in these discussions, and Dr. Dickson dealt with their individual views in some detail. Research is now hampered by the fact that the limit of visual observation with the microscope has been reached, the wave-length of visible light being too great to resolve the minute detail of the sub-world inhabited by viruses and material on the borderline between living and inorganic matter. What may be happening in this unknown realm may possibly be suggested by the results of experimental work, such as that of Baly in the synthesis of sugar from carbon dioxide and water under the action of ultra-violet light.

The lecture was received with much interest and its preparation and presentation were the subject of congratulation to Dr. Dickson from the members.

April 13, 1937.—The 47th regular meeting was held in the Science Building, with Mr. H. P. Newton in the Chair. Minutes of the previous meeting were adopted. Mr. Newton devoted some time to current phenomena outlined in the Handbook, particularly the conjunction of the Moon and Mars on April 27th. He then referred to Whipple's comet and gave data on its position and motion, after which Mr. Jorgensen was called on to speak on "Rowland's Concave Grating and its Mounting". Mr. Jorgensen first referred to the prism type of spectroscope, analysing light by refraction, then described the method by diffraction, using a grating.

Rudimentary principles of the two methods were discussed and Mr. Jorgensen emphasized the advantage of the grating over the prism in giving equal dispersion of all colours. Rowland's concave mirror was ruled with 14,000 lines to the inch. By means of blackboard sketches Mr. Jorgensen illustrated the methods of mounting the grating with reference to the light source, slit and eyepiece, showing how means were provided for the measurement of the angles necessary to the determination of the wave-length of the light analysed.

"The 200-inch Telescope" was the subject of a brief talk by J. Teasdale in which he sketched briefly the history of the project to date. Description of the mounting was aided by exhibition of a small model.

The various optical combinations were described with some details of the main mirror and the theoretical powers possible with such an instrument, but it was pointed out that the great advantage of the new instrument would be in light-grasp, much needed in research to the remote distances of space.

At the conclusion, the Chairman asked if there were any members who would like to visit the Dominion Observatory at Victoria this spring, suggesting as the most suitable date the Saturday preceding the May 24th holiday, which falls on a Monday. Six members signified their desire to go. No decision on details of arrangement was made.

J. TEASDALE, *Secretary.*

The Royal Astronomical Society of Canada

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